MI-139

# EVALUATION OF HYDRATED LIME AS AN ANTI-STRIPPING AGENT IN THE HOT-MIX RECYCLING OF A BADLY STRIPPED PAVEMENT

MATERIALS INFORMATION

ENGINEERING MATERIALS OFFICE

# EVALUATION OF HYDRATED LIME AS AN ANTI-STRIPPING AGENT IN THE HOT-MIX RECYCLING OF A BADLY STRIPPED PAVEMENT

BY

R. C. EVERS
SPECIAL PROJECTS OFFICER
BITUMINOUS SECTION

H. VILLNEFF
QUALITY ASSURANCE OFFICER
NORTHERN REGION

G. L. BERRY
MOBILE LABORATORY FOREMAN
NORTHERN REGION

D. F. LYNCH
HEAD, BITUMINOUS SECTION
ENGINEERING MATERIALS OFFICE

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## ABSTRACT

In 1988 The Ministry of Transportation, Ontario, constructed a trial incorporating hydrated lime as an anti-stripping agent in the recycling of a badly stripped pavement. Through this trial it was demonstrated that a drum-mixer could successfully be used to pre-coat both the reclaimed asphalt pavement (RAP) and the virgin aggregates with lime. The lime was added at the rate of one percent of the mass of aggregates.

The pre-coated RAP and virgin aggregates were subsequently used to produce the recycled hot-mix through the same plant.

Proprietary anti-stripping agents were used as a control on the balance of the project.

Laboratory testing of the mixes produced on this project indicate the lime is more effective as an anti-stripping agent than the two proprietary products used as the control.


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## 1 INTRODUCTION

Ontario Ministry of Transportation Contract 87-231, Highway 11, Englehart northerly to the junction of Highway 112 called for the recycling of a badly stripped asphalt pavement. As some American states have had success recycling stripped pavements using hydrated lime as an anti-stripping agent, it was decided to include a lime-treated trial for a portion of this project with a conventional proprietary anti-stripping agent as a control.

The contract required the lime to be uniformly pre-mixed through a pug-mill at the rate of 1% by weight of the respective aggregates having a minimum moisture content of 3%. However, the Contractor proposed to use his drum-mixer to perform this operation. The Ministry agreed to the Contractor's proposal on the condition that the Contractor credit the Ministry an amount equivalent to the cost of providing the pug-mill mixer.

## 2 MIX DESIGN

The mix was designed in the North Bay Regional Laboratory with materials supplied from the project site. The resulting job mix formula (JMF) was as follows:

40% milled RAP,
31% coarse aggregate (Grant stone C20-10-0),
29% fine aggregate (Grant sand C20-10-0),
3.0% new 300/400 grade asphalt cement ( 5.0% total)
1.25% (by mass of new asphalt cement) Armak CES 446 anti-stripping agent or Kling Beta HF 1250 anti-stripping agent.

This JMF produced a mix with 55% of the aggregates passing the 4.75 mm sieve and 3.9% passing the 75µm sieve with the following Marshall properties:

Voids - 3.9%,
Flow - 10.4,
Stability - 10,900 N,
VMA - 15.1%,
BRD - 2.410,
MRD - 2.509,
Retained Stability with Armak CES - 73.4%,
Retained Stability with Kling Beta HF 1250 - 81.7%.

For the lime treated mix trial, 1% lime ($CaOH_2$) by weight of aggregate would be added in place of the proprietary anti-stripping agent. The 1% lime was specified in the contract.

## 3 FIELD TRIAL

The lime trial was constructed July 4th, 5th and 6th, 1988 under clear skies and with ambient temperatures ranging between 25 and 30° C. The contractor used a Cedar Rapids TDM 88-28 drum-mixer to both pre-coat the aggregates with lime and to produce the hot-mix asphalt. The lime modified mix was the first mix placed on the project.

### 3.1 Pre-mixing The Lime

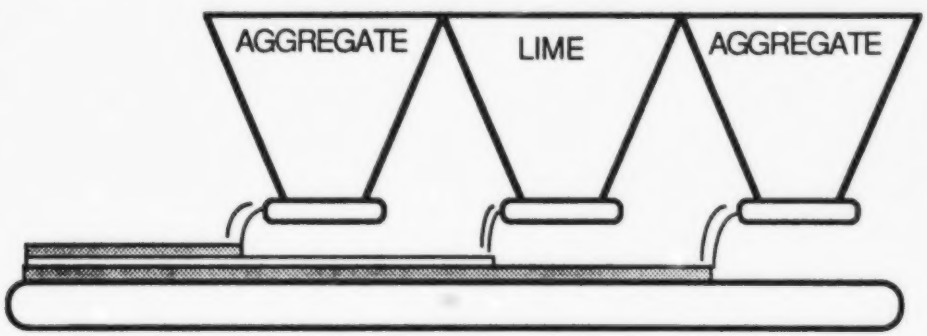
The hot-mix plant cold feed was calibrated by running each of the materials to be blended, one by one, over the belt scales and determining the mass delivered at various feeder belt rates.

The contractor determined the moisture content of the stockpiled materials to be: RAP 2.8%, stone 1.7% and sand 3.2%.

The hydrated lime was suppled to the job site in 20 kg bags aboard a flat-bed trailer. Labourers stood on the trailer, cut open the bags and emptied them into the bucket of a front-end loader. The front-end loader was then used to transport and dump the lime into the second bin of a four bin cold-feed. The aggregate or RAP to be pre-mixed with the lime was loaded and fed from bins one and three.

The aggregate or RAP from bin three was first discharged onto the gathering conveyor, followed by the lime from bin two and then aggregate or RAP from bin one, to form a lime sandwich on the belt. This "sandwich" minimized losses of the lime to the environment while passing through the grizzly screen and being transported on the feed belt to the feed inlet of the drum-mixer. A schematic drawing of the cold-feed arrangement is presented in Figure 1.

**Figure 1: Cold Feed Aggregate/Lime Proportioning**




The materials were then passed through the drum-mixer without burner or fans operating. The pre-coated aggregates/RAP mixtures were discharged from the drum-mixer into the slat conveyor which elevated the product to the top of the hot-mix storage/surge silo. Trucks were used to convey the materials from the silo to stockpiles, pushed up with a front-end loader. The stockpiled materials were covered with tarpaulins for overnight storage.

The coarse aggregate was coated first on July 4th, followed by the fine aggregate. No problems were encountered during the mixing of these two materials and both were well coated as evidenced by a uniform white appearance. The sand was found to develop a cohesive nature after being coated with lime.

Late in the day, coating of the RAP was commenced. This operation was not as successful as the previous two because the RAP became so cohesive after lime treatment that it plugged up the cone section of the silo. It took two hours to

unplug the silo and work for the day was then terminated. The next day, July 5th, RAP coating was continued with the silo being used only as a surge bin and the treated RAP being discharged into a truck whenever two or three tonnes accumulated. This was more successful, however, the silo still plugged up once more requiring twenty minutes to clear. The RAP also caused some problems at the cold feed by occasionally bridging the discharge and stopping the flow from the bin. This was attributed to the very hot weather. The lime bin also occasionally would bridge over and then collapse creating a surge of lime which would overflow the gathering conveyor.

Although there was some concern that it would be difficult to control the quantity of lime blended with the other ingredients using a drum-mixer, in actual fact, the total quantity used was 1.0% which was the target dosage.

### 3.2 Hot-mix Production

Prior to commencing hot-mix production the drum-mixer was purged of lime by turning on the exhaust fan. This resulted in heavy discharge of lime out the stack for about one and a half minutes. At this time it was discovered that the lime had plugged the wet-wash system and about twenty minutes were lost in clearing it.

Production of the lime treated hot-mix commenced at 5:00 pm July 5th. Mix was first discharged from the drum-mixer at 143° C but was subsequently lowered to 127° C because of the high ambient temperature. The exhaust from the stack was very clean with little visible emission. No problems were encountered at the plant producing the lime treated hot-mix. The first load of hot-mix left the plant at 5:30 pm.

### 3.3 Hot-mix Placement

The lime treated hot-mix was placed as a binder course from station 14+147 to 14+803, and used as padding from station 13+715 to 13+880 northbound and from station 13+715 to 13+915 southbound on July 5th. On July 6th, lime treated hot-mix was placed as surface course from station 14+075 to 15+235.

The first loads of lime treated hot-mix contained lumps of pure lime which diminished in frequency as production continued. Whenever lumps were observed in the mat, they were dug out and replaced with fresh mix. The lime treated hot-mix was very easy to place and compact but did appear to be somewhat tender. The compacted mat was very tight and rich in appearance. The rich appearance caused some observers to be concerned that the mix was flushing. Others attributed the rich appearance to the high ambient temperature and predicted it would disappear with cooler weather. Time and laboratory testing proved the latter to be correct.

Subsequent to the lime treated hot-mix trial, the balance of the contract was paved using recycled hot-mix containing either Kling Beta HF 1250 or Armak CES 446 anti-stripping agents.

## 4 TESTING

Test data is contained in the appendix.

### 4.1 Acceptance Laboratory Testing

The laboratory responsible for acceptance testing on this contract performed three extraction tests on the lime treated hot-mix. The average results of this testing indicate the mix was within very close tolerance for gradation and slightly high by 0.24% in asphalt cement content. However, these results were not corrected for fines loss from the extractor by the SMM continuous flow centrifuge which would typically lower the value by 0.15% or more.

### 4.2 Regional Mobile Laboratory Testing

A Regional Mobile Laboratory on site performed Marshall tests on two samples of the lime treated hot-mix and found the mix to conform favourably with the mix design values except for lower VMA (12.7%) and Voids (1.3%). The addition of the 1.0% lime could only be expected to lower the voids by 0.8%, so other

factors must have contributed to the voids reduction. Mix produced with the proprietary anti-stripping agents also had lower average voids and VMA than the mix design as follows:

| | | |
|---|---|---|
| Kling HF 1250 | voids - 3.3%, | VMA - 14.1%, |
| Armak CES 446 | voids - 2.7% | VMA - 14.0%. |

After vacuum saturation to determine the theoretical maximum specific gravity, no evidence of stripping was observed in the lime treated mix. In subsequent testing of mix containing the two proprietary anti-stripping agents, slight to medium stripping was evident with both.

Two extraction tests performed by this laboratory indicated that the JMF gradation was being met but that the asphalt cement content (corrected by the SMM continuous flow centrifuge for fines loss from the extractor) was low by 0.31%. The average correction for these two tests was 0.69% asphalt, whereas the average correction on samples without lime was much lower at 0.28% asphalt. This suggests that much of the lime passed along with the dissolved asphalt cement through the filter paper of the Rotarex extractor.

Six cores extracted from the completed pavement were determined to average 99% of Marshall laboratory density.

Five cores were found to average 3.4% insitu voids.

### 4.3 Head Office, Downsview Laboratory Testing

Samples of all mix ingredients, as well as samples of final mix with lime and the proprietary anti-stripping agents were shipped to the Downsview Laboratory for testing of Marshall Index of Percent Retained Stability. The results are as follows:

| MIX | | RETAINED STABILITY |
|---|---|---|
| RHM/No Additive | (Lab. Mix, Job A.C.) | 35% |
| RHM/No Additive | (Lab. Mix, Lab. A.C.) | 46% |
| RHM/Lime | (Field Mix) | 91% |
| RHM/Kling Beta HF 1250 | (Field Mix) | 82% |
| RHM/Armak CES 446 | (Field Mix) | 68% |

These results agree with the stripping observations made in the Regional Mobile Laboratory.

In addition to the above testing, the laboratory performed per cent retained strength on replicate specimens, using a test method under development by the NCHRP. No correlation was found between the results of this testing and Marshall retained stability testing.

## 5 FIELD EVALUATION

Thirteen months after construction, the project was visually inspected. The mixes constructed with the two proprietary anti-stripping agents were indistinguishable from each other with a tightly knit uniform surface. The lime mix had a slightly tighter texture than the other two and none of the three mixes exhibited any sign of stripping.

## 6 COSTS

The following 1988 costs were provided by the contractor:

Armak CES 446, $2,470.00 per tonne / $1.17 per tonne of hot-mix,

Kling Beta HF 1250, $4,210.00 per tonne / $1.79 per tonne of hot-mix,

Lime, $250.00 per tonne / $4.01 per tonne of hot-mix.

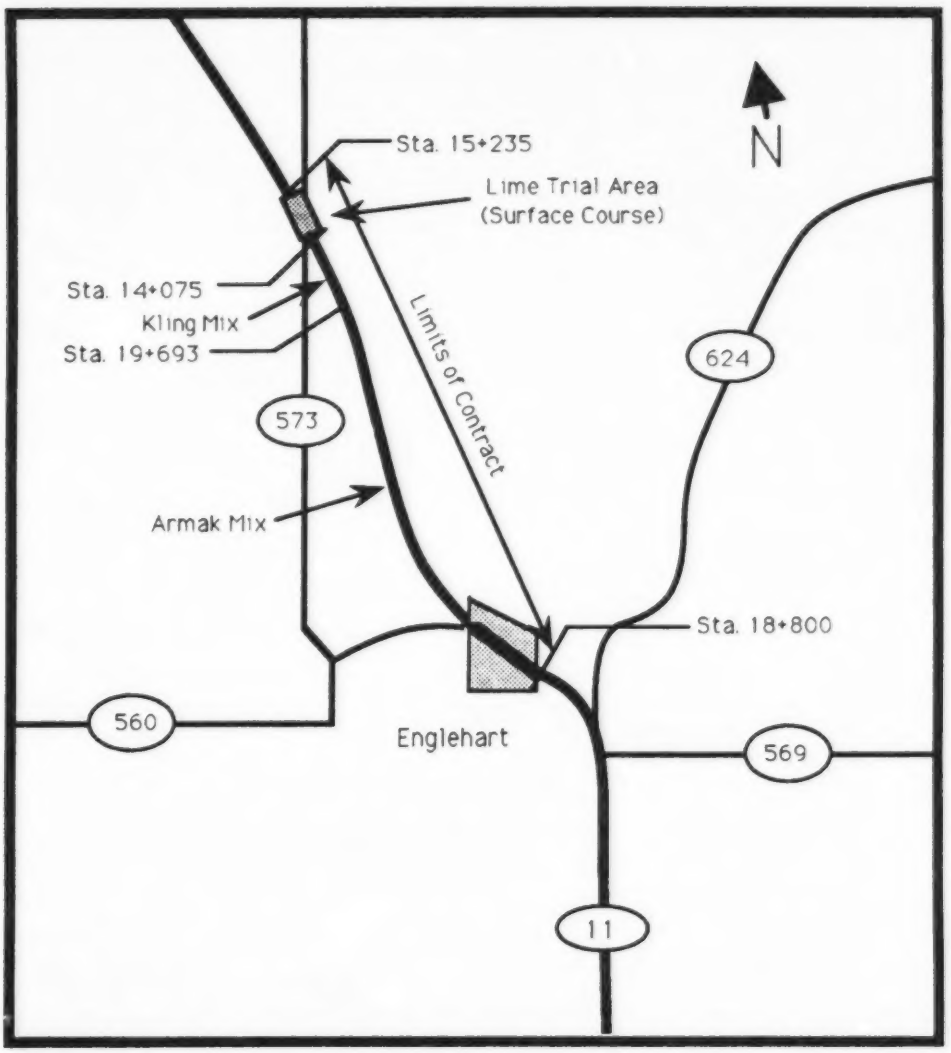
The contractor had originally estimated the cost of incorporating the lime using a pug-mill at $3.71 per tonne. The actual cost using the drum-mixer was $0.30 per tonne over estimate.

## 7 DISCUSSION

This project demonstrated the feasibility of pre-blending lime and aggregates through a drum-mixer. However, a method of introducing the lime to the cold feed, or drum, must be found to eliminate manual handling. Although the men wore gloves, goggles and dust masks the lime still caused skin irritation, particularly at the points where the protective equipment contacted the skin.

It was possible to use a drum-mixer to incorporate the lime on this project because of the small quantity involved but it would not be viable on a large project unless a second plant was used to produce the hot-mix.

# KEY MAP


N
Sta. 15+235
Lime Trial Area
(Surface Course)
Sta. 14+075
Kling Mix
Sta. 19+693
Limits of Contract
624
573
Armak Mix
Sta. 18+800
560
Englehart
569
11

## APPENDIX

### Acceptance Laboratory Results (Lime Mix)

Asphalt Content And Gradation

| | A.C. | 16.0 | 13.2 | 9.5 | 4.75 | 2.36 | 1.18 | 600 | 300 | 150 | 75 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| JMF | 5.0 | 99.1 | 91.2 | 73.9 | 55.0 | 45.1 | 34.5 | 22.9 | 11.3 | 5.7 | 3.9 |
| 1 | 5.05 | - | 94.4 | 78.4 | 57.1 | 45.3 | 33.9 | 22.9 | 12.4 | 6.5 | 4.5 |
| 2 | 5.50 | - | 91.6 | 73.4 | 54.1 | 43.2 | 32.3 | 21.6 | 11.4 | 5.7 | 3.8 |
| 3 | 5.16 | 97.9 | 89.6 | 70.0 | 52.5 | 41.3 | 31.0 | 20.6 | 10.9 | 5.5 | 3.6 |

Values not corrected for fines lost from the extractor.

### Regional Mobile Laboratory Results (Lime Mix)

Asphalt Content And Gradation

| | A.C. | 16.0 | 13.2 | 9.5 | 4.75 | 2.36 | 1.18 | 600 | 300 | 150 | 75 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| JMF | 5.0 | 99.1 | 91.2 | 73.9 | 55.0 | 45.1 | 34.5 | 22.9 | 11.3 | 5.7 | 3.9 |
| 1 | 4.77 | 99.4 | 93.9 | 76.8 | 55.9 | 44.2 | 33.4 | 23.2 | 11.6 | 6.6 | 4.5 |
| 3 | 4.61 | - | 92.4 | 73.9 | 52.9 | 42.3 | 32.2 | 22.4 | 11.4 | 6.6 | 4.7 |

Values corrected for fines lost from the extractor by SMM high speed centrifuge.

Marshall Values

| Lot # | Voids | VMA | Stability | Flow | BRD | MRD |
|---|---|---|---|---|---|---|
| 1 | 1.4 | 13.0 | 10127 | 10.7 | 2.464 | 2.515 |
| 3 | 1.2 | 12.4 | 10404 | 12.7 | 2.477 | 2.522 |

Cores For Thickness And Compaction

| Lot/ Sublot | Core Thickness (mm) | Core BRD | Marshall BRD | Percent Compaction | Insitu Voids |
|---|---|---|---|---|---|
| 1/1 | 40 | 2.453 | 2.458 | 99.8 | |
| 1/2 | 40 | 2.453 | 2.463 | 99.6 | |
| 1/3 | 38 | 2.369 | 2.433 | 97.4 | |
| 2/2 | 60 | 2.416 | 2.449 | 98.7 | 4.2 |
| 2/3 | 54 | 2.427 | 2.448 | 99.1 | 3.8 |
| 2/4 | 56 | 2.432 | 2.447 | 99.4 | 3.6 |

Cores For Insitu Voids

| Lot/ Sublot | Core BRD | MRD | Insitu Voids |
|---|---|---|---|
| 1/4 | 2.451 | 2.523 | 2.9 |
| 2/1 | 2.464 | 2.526 | 2.5 |

**Downsview Development Laboratory**

| MIX | | RETAINED STRENGTH* |
|---|---|---|
| RHM/No Additive | (Lab. Mix, Job A.C.) | 85% |
| RHM/No Additive | (Lab. Mix, Lab. A.C.) | 60% |
| RHM/Lime | (Field Mix) | 65% |
| RHM/Lime | (Lab. Mix) | 81% |
| RHM/Kling Beta HF 1250 | (Field Mix) | 81% |
| RHM/Kling Beta HF 1250 | (Lab. Mix, Lab. Kling) | 67% |
| RHM/Armak CES 446 | (Field Mix) | 84% |

* Test method under development by NCHRP.